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Palynofossils from the Baratang Formation of Andaman Sea and their biostratigraphic significance

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ABSTRACT

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The present work incorporates the results of palynostratigraphical investigations of the Baratang Formation (Cretaceous-Eocene) from the Baratang Island of Andaman Sea, India. Several rich palynofloral associations have been studied from the measured stratigraphic sections of the Baratang Formation exposed on the Andaman Trunk Road from Nilambar Jetty towards Gandhi Jetty in the Baratang Island. The principal rock types of this formation include marine shales, siltstones, silty sandstones and limestones. The palynofloral assemblage consists of a variety of dinoflagellate cysts, spores, pollen grain, fungal and algal remains. The chief constituents of the assemblage are mainly early to middle Eocene dinoflagellate cysts, viz. *Enneadocysta arcuatum*, *Cordosphaeridium gracile*, *Operculodinium exquisitum, O. centrocarpum, Homotryblium tenuispinosum, H. oceanicum* and *Achomosphaera multifurcata*. On the other hand, *Cyathidites australis, Retitrisyncolpites thaungii, Lakiapollis ovatus, Acanthotricolpites kutchensis* and *Neocouperipollis brevispinosus* are some of the associated land-derived palynofossils. Quantitatively, dinoflagellate cysts and acritarchs dominate the assemblage in the lower horizons. A large number of reworked palynofossils have also been recorded from the younger horizons of the investigated sections. Biostratigraphic significance of the recorded palynotaxa is highlighted in the current study. The palynoflora indicates the prevalence of tropical to subtropical warm, humid climate in the areas of investigation. A concise discussion on the provenance of the recorded palynofossils has also been presented herein.

Keywords: Palynofossils, dinoflagellate cysts, Eocene, Baratang Formation, Andaman and Nicobar Islands, India.

INTRODUCTION

The rocks of the Baratang Formation (Cretaceous-Eocene) contribute an important succession in the Tertiary strata of the Andaman-Nicobar Islands pertinent to the Indian subcontinent. These flysch-turbidite deposits attracted the attention of few palaeontologists in the 20th century due to their rich faunal assemblages. However, palynological data available from these sediments is very scanty as most of the investigated samples from these difficult areas have been found to be barren or characterized by very low yield of palynofossils. During palynological investigation of the Palaeogene rocks of the Andaman–Nicobar Islands, a rich palynofloral assemblage has been recovered from the Adazig area of the Baratang Island. Considering their potential to provide valuable palaeoclimatic and palaeoenvironmental data from this region during the Palaeogene period, a detailed palynological study of the Baratang Island and its adjoining areas were undertaken. The present paper reports the preliminary

results of the palynological investigation of the Baratang Island for deciphering the age of the constituent sediments.

PREVIOUS WORK

The palynological studies till date from the flysch–turbidite sediments of the Andaman–Nicobar Basin are very limited and confined mainly to the Middle Andaman and Baratang Islands (Banerjee 1966, 1967, Mathur & Mathur 1980, Sharma and Mehrotra 1984, Sharma & Sarjeant 1987, Mandal et al. 1994, Jafar & Tripathi 2001). Banerjee (1966) for the first time recorded a Palaeogene palynofloral assemblage of the Port Blair Formation from the Baratang Islands. Later on, a late Cretaceous palynofloral assemblage was also recorded from the Middle Andaman (Banerjee 1967) which is closely comparable with the corresponding assemblages from Assam, Bengal and Krishna-Godavari basins. The palynoflora from the upper part of the Baratang Formation, Middle Andaman closely resembles the palynoassemblage of Laisong and Burdwan formations of Assam and Bengal basins respectively (Mathur & Mathur 1980). Late Triassic terrestrial palynomorphs and dinoflagellate cysts were also documented from the Middle Andaman (Sharma & Mehrotra 1984). Early Eocene palynofossils along with reworked Gondwana palynofossils were recovered from the Baratang Formation that showed close affinity to the early Eocene flora of Myanmar (Mandal et al. 2003). A rich palynofloral assemblage consisting of spores, pollen and dinoflagellate cysts belonging to the late Cretaceous to Oligocene interval has been recorded from ooze of mud volcanoes of the Baratang Island (Mandal et al. 1996). Jafar and Tripathi (2001) reported late Triassic palynofossils mixed with late Cretaceous palynofloral assemblage from the Middle Andaman. Recorded palynofloral assemblage from the Baratang Island differs considerably among different case studies by various authors possibly due to the difference in facies or the variable intervals of deposition. However, all the palynofloral assemblages possess large number of recycled Gondwana palynofossils of different ages.

GEOLOGICAL SETTING

The Andaman-Nicobar Group of Islands lie in a long and narrow broken chain approximately north–south sprawling like an arc, and are situated between 06º N and 14º N latitude and 92º E and 94º E longitude. Geologically, these Islands appear to have been part of the major landmass of SE Asia comprising north–east India, Burma, Thailand, Malaysia and Indonesia. The sedimentary sequence in these Islands occurs in two set of exposures. North, Middle, Baratang and South Andaman Islands are in the primary part whereas several small Islands on the east and west side come in the second. The primary chain of islands ranges in age from late Cretaceous to Oligocene while the peripheral chain of Islands is Neogene in age. The sediments of the main Andaman Islands are deep-sea flysch sediments, which were deposited through turbidity currents (Karunakaran et al. 1964, Pandey 1972, Pandey et al. 1992). These flysch sediments are classified into two formations, namely the Baratang and the Port Blair formations (Chatterjee 1967) with an unconformable contact. The name 'Baratang Formation' was first proposed by Boileau (1950) after the Baratang Islands, for the thick black argillites and limestone sequence deposited prior to the Eocene transgression. The sediments of the Baratang Formation are mainly argillaceous and can be easily differentiated from the overlying arenaceous Port Blair Formation. The marine fossils are scantily reported in the flysch sequences of the main Islands.

MATERIALS AND METHODS

Recorded palynofloral assemblage has been recovered from five outcrop sections which lie on the western side of the main national highway (Andaman Trunk Road) from Gandhi Nagar Jetty towards the Nilambar Jetty (Figure 1). The studied sections consist mainly of black splintery siltstones, grey claystones, clay bands and limestones (Figure 2). Altogether, 28 samples were processed for this investigation. Out of these, 12 samples yielded the necessary and desired palynofossils following the usual maceration procedure using HCl,

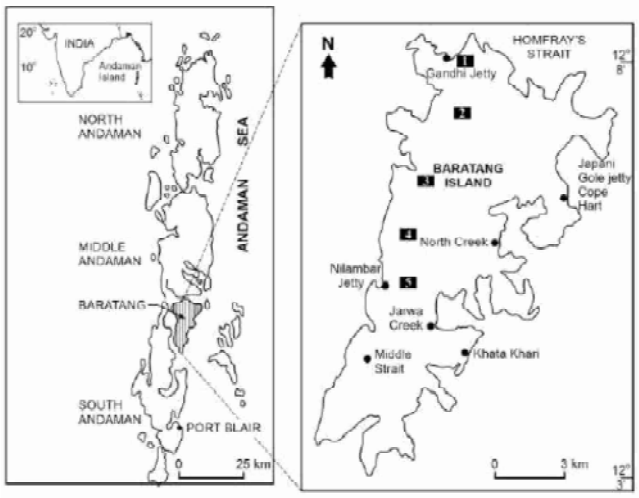

Figure 1. The Andaman Islands in the Andaman Sea, with the Baratang Island highlighted in the right frame. Black Boxes with numbers indicate the sample collections sites (modified after Rajshekhar et al. 1990).

HF, HNO_3 and 5% KOH solution. The polliniferous residue was mixed with polyvinyl alcohol and spread over the cover slip. After drying the coverslip, it was mounted in Canada balsam. The slides have been deposited in the repository of Birbal Sahni Institute of Palaeosciences, Lucknow

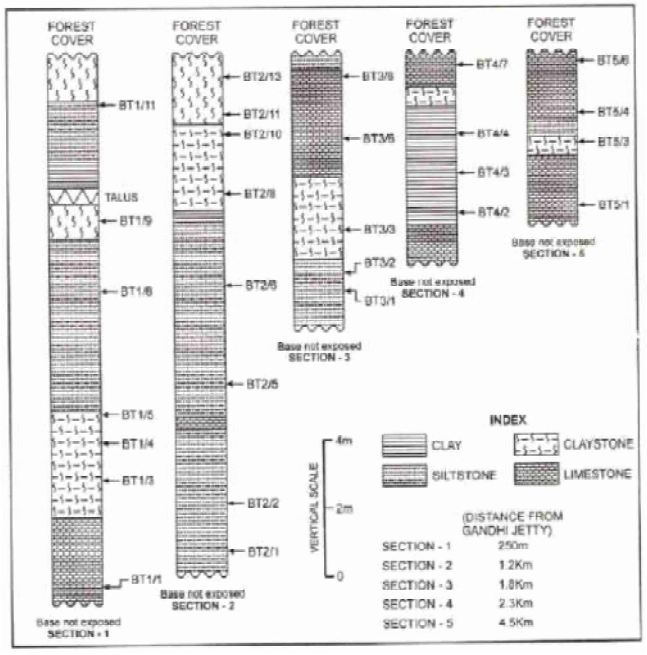

Figure 2. Lithocolumns of the studied sections with sampling sites marked by arrows.

CHECKLIST OF PALYNOFOSSILS

A checklist of the recorded palynotaxa is given below. Some selected well preserved palynofossils have been illustrated (Figures 3–4). Palynotaxa are arranged alphabetically in the following groups: dinoflagellate cysts, pteridophytic spores, gymnosperm and angiosperm pollen, fungal remains and reworked pre-Tertiary palynofossils.

Dinoflagellate cysts

Achomosphaera alcicornu (Eisenack) G.L. Eaton 1976
A. multifurcata K.P. Jain & K.K. Tandon 1981
A. sagena Davey & G.L. Williams 1966a
Araneosphaera araneosa G.L. Eaton 1976
Areoligera senonensis Lej.-Carp. 1938
Ceratiopsis leptoderma Vozzhenikova 1963 (reworked)
Cleistosphaeridium brevispinosum K.P. Jain & Millepied 1975
Cordosphaeridium fibrospinosum Davey & G.L. Williams 1966b
C. gracile (Eisenack) Davey & G.L. Williams 1966b
C. inodes (Klumpp) Eisenack 1963
C. multispinosum Davey & G.L. Williams 1966b
Deflandrea phosphoritica Eisenack 1938 (reworked)
Enneadocysta arcuata (G.L. Eaton) Stover & G.L. Williams 1995
Glaphyrocysta vicina G.L. Eaton 1976
Homotryblium abbreviatum G.L. Eaton 1976
H. floripes Deflandre & Cookson 1955
H. oceanicum G.L. Eaton 1976
H. pallidum Davey & G.L. Williams 1966b
H. tenuispinosum Davey & G.L. Williams 1966b
Hystrichosphaeridium tubiferum (Ehrenb.) Davey & G.L. Williams 1966b
Impletosphaeridium sp.
Lejeunecysta hyalina (Gerlach) Artzner and Dorhofer 1978
Lingulodinium machaerophorum (Deflandre & Cookson) Wall 1967
Operculodinium centrocarpum (Deflandre & Cookson) Wall 1967
O. exquisitum Islam 1983
Palaeocystodinium hampdenense (G.J. Wilson) Wrenn & Hart 1988 (reworked)
Polysphaeridium subtile Davey & G.L. Williams 1966b
Sentusidinium rioultii (Sarjeant) Sarjeant & Stover 1978
Spiniferites membranaceus (Rossignol) Sarjeant 1970
S. pseudofurcatus (Klumpp) Sarjeant 1970
Veryachium sp. (*Incertae sedis*)

Pteridophytic spores

Cyathidites australis Couper 1953
C. minor Couper 1953
Dictyophyllidites sp.
Hammenisporis paucicostatus (R.K. Kar) R.K. Saxena & G.K. Trivedi 2009

Hammenisporis susannae (Hammen) R.K. Saxena & G.K. Trivedi 2009
Lygodiumsporites eocenicus S.K. Dutta & S.C.D. Sah 1970
L. lakiensis S.C.D. Sah & R.K. Kar 1969
Lygodiumsporites sp.
Polypodiaceaesporites sp.
Polypodiisporites impariter (R. Potonié & S.C.D. Sah) S.K. Dutta & S.C.D. Sah 1970
Todisporites major Couper 1958
T. minor Couper 1958

Gymnosperm pollen

Podocarpidites khasiensis S.K. Dutta & S.C.D. Sah 1970

Angiosperm pollen

Acanthotricolpites kutchensis (R.K. Kar & Madh. Kumar) Alp. Singh & B.K. Misra 1991
Baculimonocolpites andamanensis Mandal et al. 1994
Lakiapollis ovatus Venkatach. & R.K. Kar 1969
Lanagiopollis regularis Morley 1982
Liliacidites sp.
Minutitricolporites minutus R.K. Kar 1985
Monocolpites spinosus Baksi 1962
Neocouperipollis brevispinosus (B. Biswas) Sam. Sarkar & H.P. Singh 1988
Pelilicieroipollis sp.
Polyadopollenites miocenicus Ramanujam 1966
Proxapertites operculatus Hammen 1956
Retinomonosulcites ellipticus (Venkatach. & R.K. Kar) R.K. Kar 1985
Retistephanocolpites kutchensis R.K. Saxena 1979
Retitrisyncolpites thaungii Mandal et al. 1994
R. reimannii Mandal et al. 1994
Striacolporites cephalus S.C.D. Sah & R.K. Kar 1970
Tricolporopilites pseudoreticulatus R.K. Kar 1985

Fungal remains

Dicellaesporites popovii Elsik 1968
Dicellaesporites sp.
Inapertisporites circularis Sheffy & Dilcher 1971
Inapertisporites sp.
Phragmothyrites eocaenicus Edwards emend. R.K. Kar & R.K. Saxena 1976

Reworked pre-Tertiary palynofossils

Alisporites grandis (Cookson) Dettmann 1963
Araucariacites australis Cookson 1947
Caheniasaccites indicus Sur. C. Srivast. 1970
Callialasporites dampieri (Balme) Dev 1961
Dactylopollis magnificus Muller 1968
Densipollenites invisus Bharadwaj & Salujha 1964
Faunipollenites varius Bharadwaj emend. Tiwari et al. 1989
Indotriradites korbaensis Tiwari 1964
Klausipollenites schaubergeri (R. Potonié & Klaus) Janson. 1962
Scheuringipollenites maximus (Hart) Tiwari 1973
Striatites varius R.K. Kar 1968
Triporoletes reticulatus (Pocock) Playford 1971

RESULTS AND DISCUSSION

The recorded palynofloral assemblage is well preserved. It mainly consists of dinoflagellate cysts, pteridophytic spores, gymnosperm and angiosperm pollen, and fungal spores and ascostromata. The dinocyst assemblage is quite rich and shows good level of diversity. *Enneadocysta arcuatum* is the most dominant taxon. Some of the associated dinoflagellate cysts are *Cordosphaeridium gracile*, *C. inodes*, *Deflandrea phosphoritica*, *Operculodinium exquisitum, O. centrocarpum, Palaeocystodinium hampdenense, Homotryblium oceanicum*, *H. tenuispinosum*, and *Achomosphaera multifurcata*. Some of the significant associated terrestrial palynofossils recorded from the sediments are *Cyathidites australis*, *Acanthotricolpites kutchensis*, *Retitrisyncolpites thaungii, R. reimannii* and *Neocouperipollis brevispinosus* etc. The reworked pre-Tertiary palynofossils are very common in the middle part of the succession but they get scarce in numbers towards the upper level. An analysis of the present Baratang palynofloral assemblage reveals that out of the total record of 46 genera and 66 species, 19 genera and 30 species belong to algae, 7 genera and 13 species belong to pteridophytes, 1 genus and 1 species belong to gymnosperms, 16 genera and 17 species belong to angiosperms, 3 genera and 5 species belong to fungal spores and ascostromata. The recovered palynofossils have been compared with the modern families. On the basis of this comparison, it has been surmised that some of them represent the spores and pollen grains of the families *Cyatheaceae*, *Lygodiaceae*, *Polypodiaceae*, *Parkeriaceae*, *Podocarpaceae*, *Arecaceae*, *Alangiaceae* and *Meliaceae*. The occurrences of the above mentioned families indicate the prevalence of a subtropical to tropical climate which was very warm and humid. Dinoflagellate cysts recorded in the present investigation also indicates a deep marine environment prevailed during the deposition of the Baratang sediments. Pandey et al. (1972) reported the occurrence of 150 to 200 feet high exotic blocks of foraminiferal and algal limestones pertaining to the early Eocene shelf

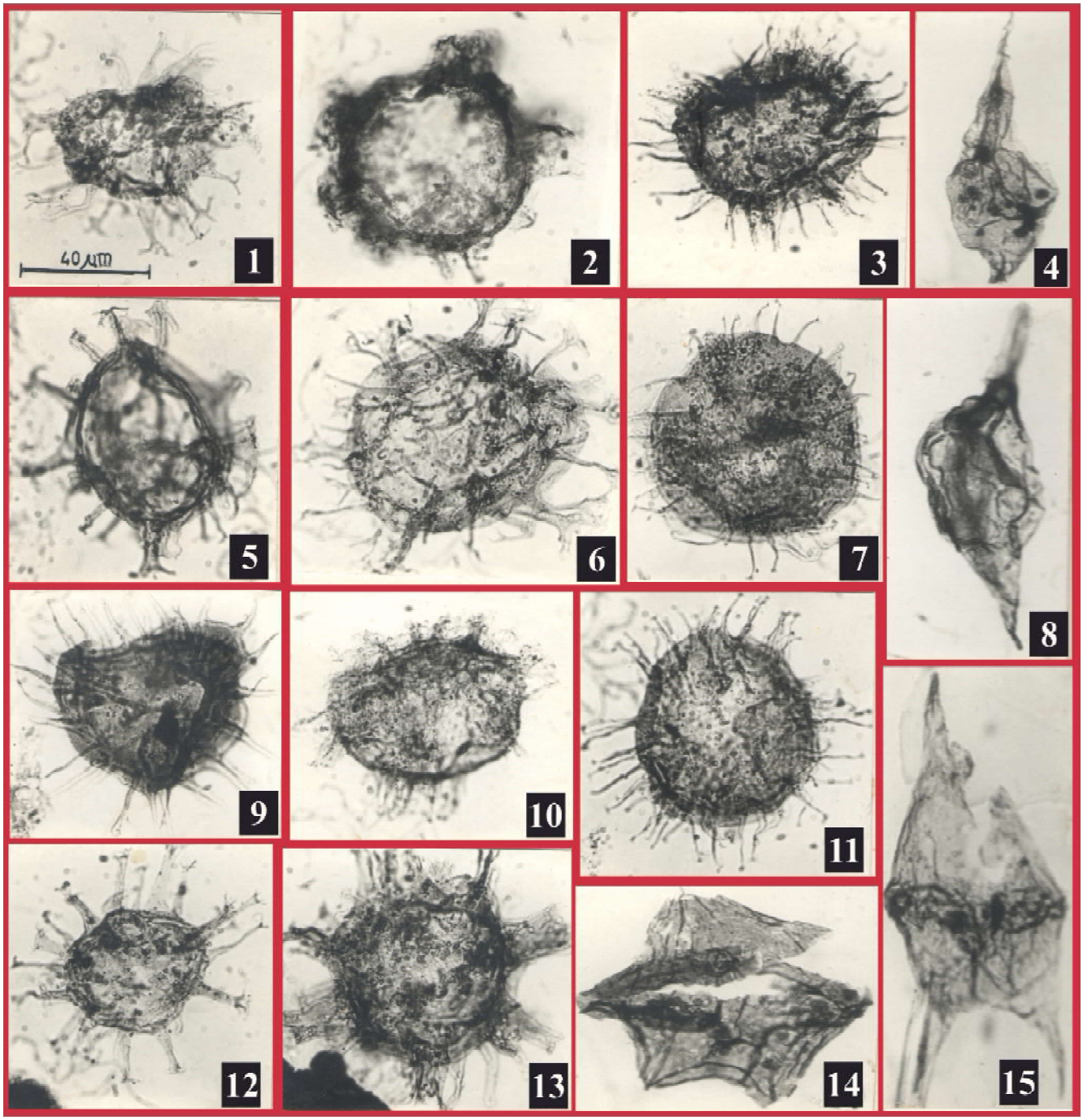

Figure 3. All photomicrographs are magnified ca. ×500 and the microscope co-ordinates are within the parenthesis. **1.** *Achomosphaera multifurcata* K.P. Jain & K.K. Tandon 1981 Slide nos. BSIP 12644 (51 × 92). **2, 13.** *Cordosphaeridium gracile* (Eisenack) Davey & Williams 1966b, Slide nos. BSIP 12642 (49 × 91); BSIP 12659 (67 × 89). **3, 11.** *Operculodinium centrocarpum* (Deflandre & Cookson) Wall 1967, Slide nos. BSIP 12655 (47 × 105); BSIP 12659 (37 × 95). **4.** *Palaeocystodinium hampdenense* (G.J. Wilson) Wren & Hart 1988, BSIP 12661 (29 × 93). **5.** *Achomosphaera sagena* Davey & Williams 1966a, Slide no. BSIP 12656 (26 × 88). **6.** *Enneadocysta arcuatum* (G.L. Eaton) Stover & Williams 1995, Slide no. BSIP 12649 (297 × 96). **7.** *Cleistosphaeridium brevispinosum* K.P. Jain & Millepied 1975, Slide no. BSIP 12657 (42 × 110). **8.** *Palaeocystodinium* sp., Slide no. BSIP 12649 (35 × 111). **9.** *Operculodinium exquisitum* Islam 1983, Slide no. BSIP 12666 (37 × 105). **10.** *Impletosphaeridium* sp., Slide no. BSIP 12661 (29 × 101). **12.** *Homotryblium floripes* Deflandre & Cookson 1955, Stover, Slide no. BSIP 12647 (31 × 96). **14.** *Lejeunecysta hyalina* (Gerlach) Artzner and Dorhofer 1978, Slide no. BSIP 12659 (67 × 89). **15.** *Ceratiopsis leptoderma* Vozzhenikova 1963, Slide no. BSIP 12761 (43 × 108).

environments. They interpreted these as fallen blocks of slipped carbonate masses from the continental shelf into the geosynclines. According to Pandey et al. (1992), outer shelf deposits of the lower Eocene were dragged towards the geosynclinal margin in a stretching of continental shelf probably during the middle Eocene when there was a rapid down subduction in the geosynclines. At the geosynclinal margin, increased slope was responsible for detachment and fall of these blocks in the geosynclines, where exotic blocks younger than early Eocene are not recorded. It suggests that probably the major event of down buckling was during middle Eocene at a time when large scale marine transgression occurred in the Assam-Arakan Basin. Occurrence of characteristic middle Eocene dinocyst taxa, viz. *E. arcuatum* and *H. oceanicum* clearly indicates that the event took place sometime during the middle Eocene, as both taxa shows FAD (First Appearance Datum) in this period. The dinoflagellate assemblage is quite rich and varied. *Enneadocysta arcuatum* is the most dominant taxon. This record is very significant in view of the fact that middle Eocene dinoflagellate cysts are being reported for the first time from these sediments. It also throws some light on the age of this Formation and its environment of deposition. The majority of the taxa are long-ranging; however, few taxa are age indicative. *Enneadocysta arcuatum* and *Homotryblium floripes* are known to occur in the middle Eocene. The reworked palynofossils are sporadically present at the base of the section which gradually decrease and get scarce towards the upper level. In the absence of any marine nannoplankton and overall scarcity of marine fauna, palynology plays an important role in the age determination of the Andaman Flysch sediments.

Some of the associated palynofossils like *Retitrisyncolpites, Baculimonocolpites, Lakiapollis ovatus, Pellicieroipollis, Proxapertites, Acanthotricolpites* and *Neocouperipollis* have limited vertical distribution. They are present abundantly in the late Palaeocene-early Eocene sediments. *Retitrisyncolpites* are dominant in the early to middle Eocene sediments. The palynology of the Baratang Island shows that constituents of the palynoassemblage are dissimilar in different sections (Mandal et al. 2003).

Several taxa, viz. *Monocolpites*, *Proxapertites, Hammenisporis* and *Neocouperipollis* are present in the Palaeocene–Eocene rocks of Assam-Arakan region. Several palynotaxa, viz. *Acanthotricolpites, Monocolpites, Minutititricolporites*, *Tricolporopilites* and *Striacolporites* are common in the Tertiary sediments of Assam and Meghalaya which are present in the Baratang palynoflora also. *Retitrisyncolpites* has been recorded in the early Eocene of Myanmar (Reimann & Thaung 1981) and Middle Andaman (Mandal et al. 1994). The taxon occurs abundantly till the middle Eocene (Reimann & Thaung 1981). Similarly, *Minutitricolporites* and *Striacolporites* are commonly present in the Palaeogene (Kar 1985). Most of the recorded palynofossils are present abundantly in the late Palaeocene-early Eocene sediments. *Lakiapollis ovatus* and *Pellicieroipollis* range within late Palaeocene to Eocene (Thanikaimoni et al. 1984, Venkatachala et al. 1989) also occurs in the early to middle Eocene sediments of Assam, Meghalaya and Myanmar. The dinoflagellate cysts *Operculodinium centrocarpum*, *Cleistosphaeridium brevispinosum* and *Polysphaeridium subtile* recorded are long-

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Figure 4. All photomicrographs are magnified ca. ×500 and the microscope co-ordinates are within the parenthesis. **1.** *Polypodiisporites impariter* (R. Potonié & S.C.D. Sah) S.K. Dutta & S.C.D. Sah 1970, Slide no. BSIP 12664 (45 × 91). **2.** *Retinomonosulcites ellipticus* (Venkatach. & R.K. Kar) Kar 1985, Slide no. BSIP 12664 (38 × 102). **3.** *Todisporites major* Couper 1958, Slide no. BSIP 12659 (47 × 93). **4, 5.** *Liliacidites* sp., Slide nos. BSIP 12658 (31 × 97); Slide no. BSIP 12659 (43 × 102). **6.** *Lygodiumsporites adriensis* (R. Potonié & Gelletich) R. Potonié et al. 1950, Slide no. BSIP 12657 (54 × 111). **7.** *Retistephanocolpites kutchensis* R.K. Saxena 1979, Slide no. BSIP 12656 (59 × 101). **8.** *Cyathidites australis* Couper 1953, Slide no. BSIP 12661 (55 × 109). **9.** *Lygodiumsporites* sp., Slide no. BSIP 12658 (20 × 108). **10.** *Cyathidites minor* Couper 1953, Slide no. BSIP 12663 (27 × 98). **11.** *Inapertisporites circularis* Sheffy & Dilcher 1971, Slide no. BSIP 12641 (47 × 99). **12.** *Dicellaesporites popovii* Elsik 1968, Slide no. BSIP 12657 (38 × 95). **13.** Angiosperm Pollen Type 1 (Tetraporate), Slide no. BSIP 12657 (39 × 97). **14.** *Veryachium* sp., Slide no. BSIP 12655 (33 × 94). **15.** *Hammenisporis susannae* (Hammen) R.K. Saxena & G.K. Trivedi 2009, Slide no. BSIP 12649 (56 × 97).

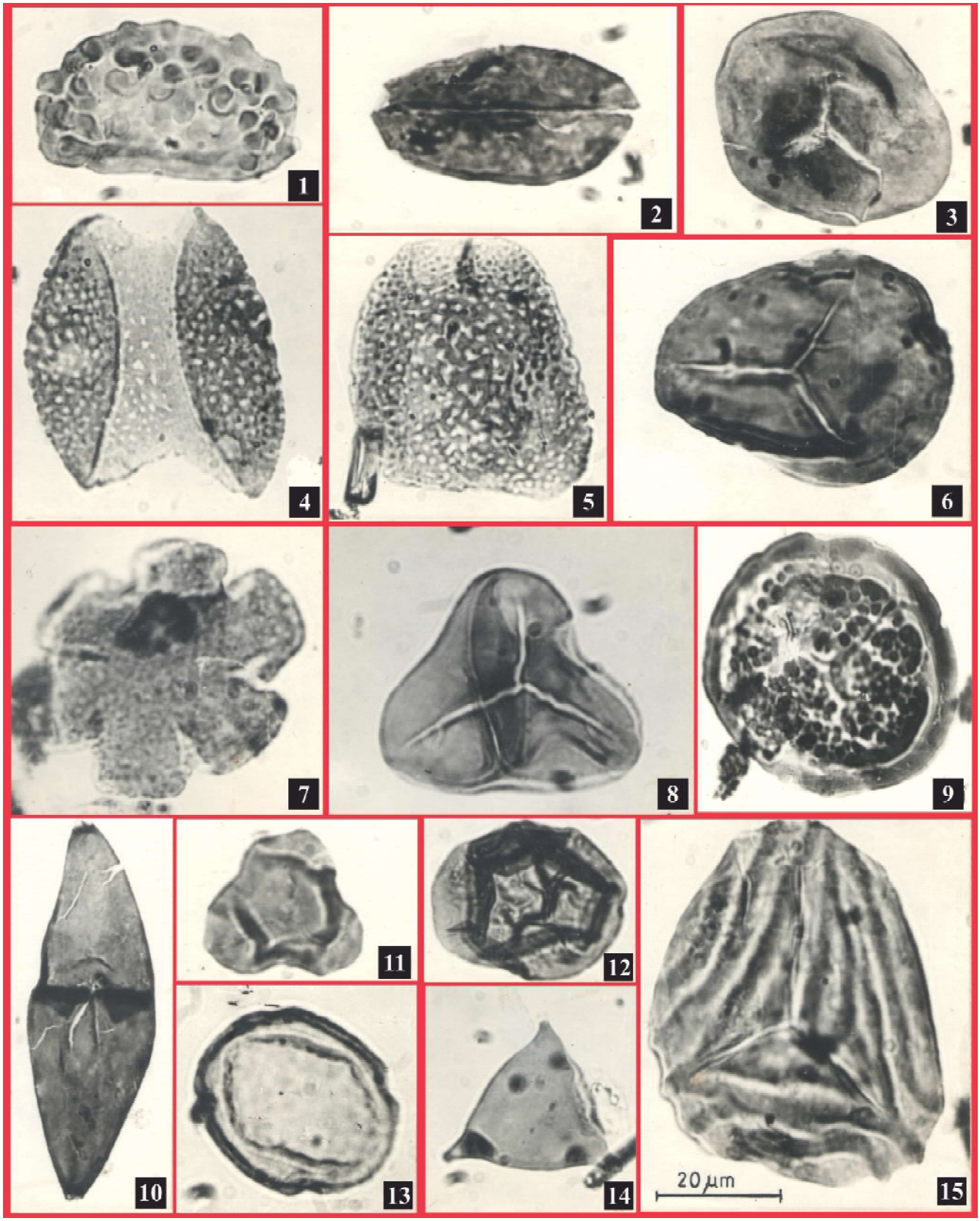

Figure 4

ranging taxa (Eocene to Miocene) but mainly dominant in the Eocene sediments. The present dinocyst assemblage is very similar to the Eocene palynofloral assemblages recorded from the Subathu Formation of Himachal Pradesh and Meghalaya, NE India (Singh et al. 1978, Sarkar & Singh 1988, Singh & Sarkar 1992, Sarkar 1997, Sarkar & Prasad 2000a, b; Sarkar et al., 2014). Considering all the above evidences, early to middle Eocene age has been assigned for the investigated samples. Some of the samples contain Permian, Triassic and Jurassic-Cretaceous palynofossils along with the early-middle Eocene palynofossils. In the Baratang Island, two horizons of fauna are known. Recycled fauna ranging in age from Cretaceous to late Eocene has also been recorded by several workers (Guha & Mohan 1965, Pandey 1972, Pandey & Rao 1976, Kumar & Soodan 1976, Pandey et al. 1992). Cretaceous planktonic foraminifera and marine algae are also recorded from this formation (Badve & Kundal 1986, Rajshekhar et al. 1990). Reworking of palynofossils is very common in the Andaman and its adjoining areas during early–middle Eocene (Banerjee 1967, Mathur & Mathur 1980) similar to the phenomenon interpreted for the Subathu sediments of Himachal Pradesh and Haryana (Sarkar & Sarkar 2023).

In the present investigation, reworked Permian, Triassic and Jurassic–Cretaceous pollen taxa of Gondwanan affinity have been recorded. These elements are interpreted to have been transported to the Andaman Islands. Late Cretaceous palynofossils in Eocene assemblage has also been recorded by Jafar & Tripathi (2001). In the present Eocene palynofloral assemblage, Permian palynotaxa, viz. *Caheniasaccites*, *Faunipollenites* and *Scheuringipollenites*; Triassic palynotaxa, viz. *Klausipollenites*; Jurassic-early Cretaceous palynotaxa, viz. *Callialasporites* and *Triporoletes* have been recorded. In our opinion, transportation of sediments containing pre-Tertiary reworked palynofossils in the Andaman was mainly from Assam and Meghalaya areas during the Eocene period, which corroborates the view of Pandey (1986). He postulated that long rivers draining through Bihar carried huge quantities of sediments and the mouth of these rivers opened in the Assam areas. As a result, spore–pollen mixed with the Gondwana palynofossils were deposited in the younger horizons of the Baratang Formation. Lithologically, the turbiditic sediments of the Andaman Islands (Baratang Formation) show gradual coarsening of sediments towards the North (Pandey et al. 1992). According to Ray (1982), Andaman flysch sequence comprises material which mainly appears to have been transported from distant distributive source situated far beyond the limits of this mobile crustal belt and was brought within through turbiditic currents. Moreover, the evidence of palaeocurrents suggests that the current flow towards the Andaman basin was from NNE or NE direction before the Oligocene (Bender 1983). All these data provide cogent evidences that the main source of sediments of the Baratang Island is the Assam-Meghalaya region during the Eocene epoch.

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